

# SELF ALIGNED FLOATING GATE FLASH CELL SYSTEM AND METHOD

## BACKGROUND OF THE INVENTION

The present invention relates to the field of semiconductor  
5 manufacture and, more particularly, to a flash memory device and  
method of fabrication.

As computers become increasingly complex, the need for  
improved memory storage, and in particular the need for an  
increased number of memory cells per unit area, increases. At the  
10 same time, there is a continuing drive to minimize the size of  
computers and memory devices. Accordingly, it is a goal of memory  
device fabrication to increase the number of memory cells per  
unit area or wafer area.

A conventional non-volatile semiconductor memory device in  
15 which contents are electrically programmable and simultaneously  
erased by one operation is a flash memory device. Flash memory  
allows for blocks of memory cells to be erased in one operation.  
Flash memory devices have the characteristics of low power and  
fast operation making them ideal for portable devices. Flash  
20 memory is commonly used in portable devices such as laptop or

notebook computers, digital audio players and personal digital assistant (PDA) devices.

5 In flash memory, a charged floating gate is one logic state, typically represented by the binary digit 1, while a non-charged floating gate is the opposite logic state typically represented by the binary digit 0. Charges are injected or written to a floating gate by any number of methods, including avalanche injection, channel injection, Fowler-Nordheim tunneling, and channel hot electron injection, for example.

10 An important parameter for a flash memory cell is the capacitive coupling of the memory cell. It is difficult to reduce the size or scale down the memory cell while maintaining a desired or required capacitive coupling. This parameter can be a significant factor in the drive to reduce memory cell size.  
15 Accordingly, there is a need for a memory cell production scheme directed to reducing the size of a memory cell while maintaining or improving the capacitive coupling of the memory cell.

### SUMMARY OF THE INVENTION

This need is met by the present invention, wherein a stacked gate region of a memory cell is disclosed. The flash memory device includes a substrate, at least one trench, an oxide layer, at least one floating gate and at least one polysilicon wing. The substrate has at least one semiconductor layer. The at least one trench is formed in the substrate and filled with an oxide. The oxide layer is formed over the substrate and the trench. The at least one floating gate is formed over the oxide layer. The at least one polysilicon wing is formed adjacent to vertical edges of the at least one floating gate and over the oxide layer. Other methods and devices are disclosed.

The present invention includes polysilicon wings or ears which can increase the capacitive coupling of memory cells in memory devices in which they are used. Generally, the polysilicon wings or ears are placed proximate to the floating gate of a memory cell. Thus, the present invention may allow for further reducing or scaling the size of memory cells and devices.

According to one embodiment of the invention, a stacked gate region of a memory cell is disclosed having a substrate, at least one trench, a field oxide region, a tunnel oxide layer, at least one floating gate layer and at least one polysilicon wing. The substrate has at least one semiconductor layer. The at least one

trench is formed in the substrate. The field oxide region is formed in the trench. The tunnel oxide layer is formed over the substrate. The at least one floating gate is formed over the tunnel oxide layer. The at least one polysilicon wing is formed adjacent to the at least one floating gate layer and over a portion of the field oxide region.

According to another embodiment of the invention, a stacked gate region of a memory cell is disclosed. The stacked gate region includes a substrate, at least one trench, field oxide, a tunnel oxide layer, at least one floating gate and at least one polysilicon ear. The substrate has at least one semiconductor layer. The at least one trench is formed in the substrate. The field oxide is deposited in the at least one trench and extends above an upper surface of the substrate. The tunnel oxide layer is formed over at least a portion of the substrate. The at least one floating gate layer is formed over the tunnel oxide layer. The at least one polysilicon ear is formed on the at least one floating gate layer and adjacent to the field oxide.

According to yet another embodiment of the invention, a stacked gate region of a memory cell is disclosed. The stacked gate region includes a substrate, at least one trench, a tunnel oxide layer, at least one floating gate layer, field oxide and at least one polysilicon ear. The substrate has at least one

semiconductor layer. The at least one trench is formed in the substrate. The tunnel oxide layer is formed over at least a portion of the substrate. The at least one floating gate layer is formed over the oxide layer. The field oxide is deposited in the at least one trench. The at least one polysilicon ear is formed on the at least one floating gate layer.

According to yet another embodiment of the invention, a stacked gate region of a memory cell is disclosed. The stacked gate region includes a substrate, a plurality of trenches, a tunnel oxide layer, at least one floating gate layer, field oxide regions and a pair of polysilicon wings. The substrate has at least one semiconductor layer. The plurality of trenches are formed in the substrate. The respective field oxide regions are formed in the trenches. The tunnel oxide layer is formed over the substrate. The floating gate layer is formed over the tunnel oxide layer. The pair of polysilicon wings are located adjacent to opposite ends of the floating gate layer, co-planer with the floating gate layer and over a portion of corresponding ones of the field oxide regions.

According to yet another embodiment of the invention, a stacked gate region of a memory cell is disclosed. The stacked gate region includes a substrate, a plurality of trenches, a tunnel oxide layer, at least one floating gate layer, field oxide

regions and a pair of polysilicon ears. The substrate has at least one semiconductor layer. The plurality of trenches are formed in the substrate. The respective field oxide regions are formed in the trenches. The tunnel oxide layer is formed over the substrate. The floating gate layer is formed over the tunnel oxide layer. The pair of polysilicon ears are formed adjacent to corresponding ones of the field oxide regions on the floating gate layer and projecting perpendicular to an upper surface of the floating gate layer.

According to yet another embodiment of the invention, a stacked gate region of a memory cell is disclosed. The stacked gate region includes a substrate, a plurality of trenches, a tunnel oxide layer, at least one floating gate layer, field oxide regions and a pair of polysilicon ears. The substrate has at least one semiconductor layer. The plurality of trenches are formed in the substrate. The respective field oxide regions are formed in the trenches. The tunnel oxide layer is formed over the substrate. The floating gate layer is formed over the tunnel oxide layer. The pair of polysilicon ears are formed adjacent to the floating gate layer.

According to yet another embodiment of the invention, a memory cell is disclosed. The memory cell includes a substrate, a source, a drain, at least one trench, a field oxide region, a

tunnel oxide layer, at least one floating gate layer, at least one polysilicon wing, a dielectric layer and a control gate. The substrate has at least one semiconductor layer. The source is formed in the substrate. The drain is formed in the substrate.

5 The at least one trench is formed in the substrate. The field oxide region is formed in the trench. The tunnel oxide layer is formed over the substrate. The at least one floating gate layer is formed over the tunnel oxide layer. The at least one polysilicon wing is formed adjacent to the at least one floating gate layer and over a portion of the field oxide region. The dielectric layer is formed over the substrate and the floating gate layer. The control gate layer is formed over the dielectric layer.

10 According to yet another embodiment of the invention, a memory cell is disclosed. The memory cell includes a substrate, a source, a drain, at least one trench, a field oxide region, a tunnel oxide layer, at least one floating gate layer, at least one polysilicon wing, a dielectric layer and a control gate. The substrate has at least one semiconductor layer. The source is  
15 formed in the substrate. The drain is formed in the substrate. The at least one trench is formed in the substrate. The field oxide region is formed in the trench. The tunnel oxide layer is formed over the substrate. The at least one floating gate layer  
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is formed over the tunnel oxide layer. The at least one polysilicon ear is formed on the at least one floating gate layer and adjacent to the field oxide. The dielectric layer is formed over the substrate and the floating gate layer. The control gate layer is formed over the dielectric layer.

According to yet another embodiment of the invention, a memory cell is disclosed. The memory cell includes a substrate, a source, a drain, at least one trench, a field oxide region, a tunnel oxide layer, at least one floating gate layer, at least one polysilicon wing, a dielectric layer and a control gate. The substrate has at least one semiconductor layer. The source is formed in the substrate. The drain is formed in the substrate. The at least one trench is formed in the substrate. The field oxide region is formed in the trench. The tunnel oxide layer is formed over the substrate. The at least one floating gate layer is formed over the tunnel oxide layer. The at least one polysilicon ear is formed on the at least one floating gate layer. The dielectric layer is formed over the substrate and the floating gate layer. The control gate layer is formed over the dielectric layer.

According to yet another embodiment of the invention, a method of fabricating a stacked gate region is disclosed. A substrate having at least one semiconductor layer is provided. A



tunnel oxide layer is formed over the substrate. A first polysilicon layer is formed over the tunnel oxide layer. A nitride layer is formed over the first polysilicon layer. Selected areas of the first polysilicon layer are masked.

5 Unmasked areas of the first polysilicon layer are etched leaving at least one floating gate layer. Trench areas are patterned in the substrate. Field oxide is deposited in the trench. A surface of the stacked gate structure is planarized. An oxide etch back is performed to remove selected amounts of the field oxide. The nitride layer is removed. A second polysilicon layer is deposited over the substrate. Selected portions of the second polysilicon layer are removed so as to leave polysilicon wings formed adjacent to the at least one floating gate layer and over a portion of the field oxide.

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15  
20 According to another embodiment of the invention, a method of fabricating a stacked gate region is disclosed. A substrate having at least one semiconductor layer is provided. A tunnel oxide layer is formed over the substrate. A first polysilicon layer is formed over the tunnel oxide layer. A nitride layer is formed over the first polysilicon layer. Areas of the nitride layer and first polysilicon layer are selectively removed leaving at least one floating gate layer. Trench areas are patterned in the substrate. Field oxide is deposited in the trench areas. A

surface of the stacked gate region is planarized. The nitride layer is removed. A second polysilicon layer is deposited over the substrate. Portions of the second polysilicon layer are selectively removed leaving single sided ears, each having one vertical side adjacent to sides of the field oxide and one lower side on one of the at least one floating gate layer.

According to yet another embodiment of the invention, a method of fabricating a stacked gate region is disclosed. A substrate having at least one semiconductor layer is provided. A tunnel oxide layer is formed over the substrate. A first polysilicon layer is formed over the substrate. A nitride layer is formed over the first polysilicon layer. Selected portions of the tunnel oxide layer, the first polysilicon layer, the nitride layer and the substrate are removed to form the at least one trench to a desired depth. Field oxide is deposited into the at least one trench. The field oxide and the nitride layer are planarized. The nitride layer is removed. A second polysilicon layer is deposited over the substrate and portions of the second polysilicon layer are selectively removed leaving single sided ears, each having one vertical side adjacent to sides of the field oxide and one lower side on one of the at least one floating gate layer. A portion of the field oxide is removed such that an upper surface of the field oxide is substantially

co-planer with an upper surface of the at least one floating gate layer leaving double sided ears.

According to another embodiment of the invention, a method of fabricating a memory cell is disclosed. A substrate having at least one semiconductor layer is provided. A floating gate layer is formed over the substrate. A trench is formed in the substrate. A polysilicon wing is formed adjacent to a vertical edge of the floating gate.

According to still yet another embodiment of the present invention, a method of fabricating a memory cell is disclosed. A substrate having at least one semiconductor layer is provided. A floating gate layer is formed over a substrate without using photolithography. A trench is formed in the substrate. Field oxide is deposited into the trench beyond an upper surface of the floating gate layer. A polysilicon ear is formed over the floating gate layer and adjacent to an exposed vertical edge of the field oxide.

According to another embodiment of the invention, a method of fabricating a memory cell is disclosed. A substrate having at least one semiconductor layer is provided. A floating gate layer is formed over the substrate without using photolithography. A trench is formed in the substrate. Field oxide is deposited into the trench beyond an upper surface of the floating gate layer. A

polysilicon ear is formed over the floating gate layer and adjacent to an exposed vertical edge of the field oxide. Field oxide is removed such that an upper surface of the field oxide is substantially planar to the upper surface of the floating gate layer.

According to another embodiment of the invention, a method of fabricating a memory cell is disclosed. A substrate having at least one semiconductor layer is provided. A source and drain are formed in the substrate. A tunnel oxide layer is formed over the substrate. A first polysilicon layer is formed over the tunnel oxide layer. A nitride layer is formed over the first polysilicon layer. Selected areas of the first polysilicon layer are masked. Unmasked areas of the first polysilicon layer are etched leaving at least one floating gate layer. Trench areas are patterned in the substrate. Field oxide is deposited in the trench areas. A surface of the stacked gate structure is planarized. An oxide etch back is performed to remove selected amounts of the field oxide. The nitride layer is removed. A second polysilicon layer is deposited over the substrate and selected portions of the second polysilicon layer are removed so as to leave polysilicon wings formed adjacent to the at least one floating gate layer and over a portion of the field oxide. A

dielectric layer is formed over the floating gate layer. A control gate layer is formed over the dielectric layer.

According to yet another embodiment of the invention, a method of fabricating a memory cell is disclosed. A substrate having at least one semiconductor layer is provided. A source and drain are formed in the substrate. A tunnel oxide layer is formed over the substrate. A first polysilicon layer is formed over the tunnel oxide layer. A nitride layer is formed over the first polysilicon layer. Areas of the nitride layer and first polysilicon layer are selectively removed leaving at least one floating gate layer. Trench areas are patterned in the substrate. Field oxide is deposited in the trench areas. Planarization is performed. The nitride layer is removed. A second polysilicon layer is deposited over the substrate. Portions of the second polysilicon layer are removed leaving single sided ears, each having one vertical side adjacent to sides of the field oxide and one lower side on one of the at least one floating gate layer. A dielectric layer is formed over the floating gate layer, the polysilicon ears and the substrate. A control gate layer is formed over the dielectric layer.

According to another embodiment of the invention, a method of fabricating a memory cell is disclosed. A substrate having at least one semiconductor layer is provided. A source and a drain

are formed in the substrate. A tunnel oxide layer is formed over the substrate. A first polysilicon layer is formed over the substrate. A nitride layer is formed over the first polysilicon layer. Selected portions of the tunnel oxide layer, the first polysilicon layer, the nitride layer and the substrate are removed to form at least one shallow trench to a desired depth. Field oxide is deposited into the at least one shallow trench. The field oxide and the nitride layer are planarized to create a planar surface of the stacked gate structure. The nitride layer is removed. A second polysilicon layer is formed over the substrate and portions of the second polysilicon layer are removed leaving single sided ears, each having one vertical side adjacent to sides of the field oxide and one lower side on one of the at least one floating gate layer. A portion of the field oxide is removed such that an upper surface of the field oxide is substantially co-planer with an upper surface of the at least one floating gate layer leaving double sided ears. A dielectric layer is formed over the floating gate layer, the polysilicon wings and the substrate. A control gate layer is formed over the dielectric layer.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The following detailed description of the present invention can be best understood when read in conjunction with the accompanying drawings, where like structure is indicated with  
5 like reference numerals.

Figure 1A illustrates a memory array according to one embodiment of the invention.

Figure 1B illustrates a cross section of a selected portion of a memory cell according to one embodiment of the invention.

Figure 2 illustrates a cross section of selected portion of a memory cell according to another embodiment of the invention.

Figure 3 illustrates a cross section of selected portion of a memory cell according to another embodiment of the invention.

Figure 4 illustrates a method of fabricating a memory cell according to one embodiment of the invention.

Figure 5A illustrates a stage of fabrication of the method of figure 4.

Figure 5B illustrates a stage of fabrication of the method of figure 4.

Figure 5C illustrates a stage of fabrication of the method of figure 4.

Figure 5D illustrates a stage of fabrication of the method of figure 4.

Figure 5E illustrates a stage of fabrication of the method of figure 4.

Figure 5F illustrates a stage of fabrication of the method of figure 4.

5 Figure 5G illustrates a stage of fabrication of the method of figure 4.

Figure 6 illustrates a method of fabricating a selected portion of a memory cell according to another embodiment of the invention.

Figure 7A illustrates a stage of fabrication of the method of figure 6.

Figure 7B illustrates a stage of fabrication of the method of figure 6.

Figure 7C illustrates a stage of fabrication of the method of figure 6.

Figure 7D illustrates a stage of fabrication of the method of figure 6.

Figure 7E illustrates a stage of fabrication of the method of figure 6.

20 Figure 7F illustrates a stage of fabrication of the method of figure 6.



Figure 8 illustrates a method of fabricating selected portion of a memory cell according to another embodiment of the invention.

Figure 9A illustrates a stage of fabrication of the method  
5 of figure 8.

Figure 9B illustrates a stage of fabrication of the method of figure 8.

Figure 9C illustrates a stage of fabrication of the method of figure 8.

Figure 9D illustrates a stage of fabrication of the method of figure 8.

Figure 9E illustrates a stage of fabrication of the method of figure 8.

Figure 9F illustrates a stage of fabrication of the method of figure 8.

Figure 9G illustrates a stage of fabrication of the method of figure 8.

Figure 10 is a computer system with which embodiments of the invention may be used.

# DETAILED DESCRIPTION OF THE INVENTION

Figure 1A illustrates a memory array 260 according to one embodiment of the invention. The memory array 260 includes a plurality of memory cells 190. Each memory cell 190 includes a source 210, drain 220 and a stacked gate region or gate structure 200. The gate structure 200 includes a floating gate 250 and a control gate 240. The floating gate 250 includes polysilicon wings or ears, described in further detail herein, which increase the capacitive coupling of the memory cell 190. The control gates 240 of the respective cells 190 in a row are formed integral to a common word line (WL) associated with the row. In the completed memory array, the source 210 of each memory cell 190 in a column is formed in a common region with the source 210 of one of the adjacent memory cells. Similarly, the drain 220 of each memory cell is formed in a common region with the drain 220 of another adjacent memory cell. Additionally, the sources 210 of each memory cell 190 in a row, and hence pair of rows, are formed as a common region, facilitating formation of a common source line CS. The drain of each cell in a row of cells is connected by a conductive bit line (BL). A memory array of this nature, but without polysilicon wings or ears, is illustrated in further detail in U.S. Patent No. 5,680,345, the disclosure of which is incorporated herein by reference.

To effect a charge on floating gate 250, the voltage on control gate 240 is capacitively coupled to floating gate 250, which permits control gate 240 to control the voltage on floating gate 250. Inadequate capacitive coupling between control gate  
5 240 and floating gate 250 may inhibit proper operation of memory cell 190. The degree or amount of capacitive coupling is increased by increasing the overlapping surface area of control gates 240 to floating gates 250. Control gate 240 and floating gate 250 generally comprise parallel planes of conductive material separated by a dielectric layer. If the floating gate 250 is too small, the effectiveness of the coupling degrades and adversely affects the threshold voltage. Consequently, each floating gate 250 must provide sufficient area to effectively couple control gate 240 to floating gate 250. By including polysilicon wings or ears of the present invention, as described in further detail herein, with the floating gate 250, the lateral dimensions of the floating gate 250 can be reduced, thereby reducing the size of the memory cell, while maintaining an appropriate capacitive coupling.

20 Figure 1B illustrates a stacked region of a memory cell according to one embodiment of the invention. The illustrated portion of the memory cell includes a substrate 101, a tunnel oxide layer 102, a floating gate (FG) polysilicon (poly) layer

103, floating gate poly wings 104, a field oxide region 105, a  
dielectric layer 106 and a control gate layer 107. The substrate  
101 is generally silicon, but other types of semiconductor  
materials may be used and has an upper surface 108. The field  
oxide region 105 electrically isolates individual memory cells.  
The FG poly layer 103 includes an upper surface 109. The FG poly  
layer 103 and the FG poly wings 104 typically comprise conductive  
polysilicon but need not be made of the same material. The  
configuration of the FG poly layer 103 and the FG poly wings 104  
enables formation of a memory cell characterized by higher  
capacitive coupling between the FG structure and the control gate  
layer 107. The FG poly wings 104 overlap the field oxide region  
105. For the purpose of defining and describing the present  
invention, "wings" comprise regions of material located adjacent  
to and generally coplanar with an associated material. Wings are  
described herein as merely "generally" coplanar because it is  
contemplated that portions of a wing may extend beyond or outside  
the bounds of the plane of the associated material. In the  
embodiment of figure 1B, for example, the wings 104 are located  
adjacent to and are generally coplanar with the FG poly layer  
103. The stacked gate region of a memory cell is able to be  
fabricated without using a floating gate photolithography step.

Figure 2 illustrates a stacked region of a memory cell according to another embodiment of the invention. The illustrated portion of the memory cell includes a substrate 201, a tunnel oxide layer 202, a floating gate (FG) polysilicon (poly) layer 203, floating gate poly ears 204, a field oxide region 205, a dielectric layer 206 and a control gate layer 207. The substrate 201 is generally silicon, but other types of semiconductor materials may be used. The substrate 201 has an upper surface 208. The FG poly layer 203 includes an upper surface 209. The FG poly layer 203 and the FG poly ears 204 may be made of the same material or different material. The configuration of the FG poly layer 203 and the FG poly ears 204 results in a higher capacitive coupling between the FG poly structure and the control gate layer 207. A single side of the FG poly ears 204 contacts the field oxide region 205. For the purposes of describing and defining the present invention, "ears" comprises regions of material positioned adjacent to a portion of an associated material and projecting from or extending substantially beyond the bounds of the plane of the associated material. In the embodiment of figure 2, for example, the ears 204 are adjacent to a portion of the FG poly layer 203 and project from the FG poly layer 203 in a substantially perpendicular fashion. The poly ears 204 of figure 2 may also be

identified as "single-sided" ears because they are adjacent to field oxide on a single side. The memory cell of figure 2 may also be fabricated without using a floating gate photolithography step.

5           Figure 3 illustrates a stacked region of a memory cell according to another embodiment of the invention. The stacked region of a memory cell includes a substrate 301, a tunnel oxide layer 302, a floating gate (FG) polysilicon (poly) layer 303, floating gate poly ears 304, a field oxide region 305, a dielectric layer 306 and a control gate layer 307. The substrate 301 is generally silicon, but other types of semiconductor materials may be used. The substrate 301 has an upper surface 308. The FG poly layer 303 includes an upper surface 309. The FG poly layer 303 and the FG poly ears 304 may be made of the same material or different material. The configuration of the FG poly layer 303 and the FG poly ears 304 results in a higher capacitive coupling between the FG poly layer 303 and the control gate layer 307 for memory cells of the flash memory device. The poly ears of figure 3 may also be identified as double sided ears because both vertical sides avoid contact with the field oxide region 305. Neither side of the FG poly ears 304 overlap or contact the field oxide region 305, further increasing the capacitive coupling of the memory cells. The memory cell of

figure 3 may also be fabricated without using a floating gate photolithography step.

Figure 4 illustrates a method of fabricating the stacked gate region illustrated in figure 1B. Figures 5A, 5B, 5C, 5D, 5E, 5F and 5G illustrate stages of the method of figure 4.

A substrate 501 is provided at 401. The substrate 501 is, generally, a silicon substrate. A tunnel oxide layer 502 is formed over the substrate 501 at 402. A self aligned floating gate (SA-FG) poly layer 503 is formed over the tunnel oxide layer 502 at 403. A nitride layer 504 is formed over the SA-FG poly layer 503 at block 404. Figure 5A illustrates the stacked gate region at this stage of the method.

A layer of photo resist 505 is deposited over the nitride layer 504 in selected areas by utilizing a mask at block 405. The areas covered by the photo resist indicate areas not to be etched and permit forming gates of the flash memory device. The flash memory device is etched at block 406. Layers and substrate are removed by the etch to form a shallow trench as shown by 506 in figure 5B. The etch performed at block 406, may also be referred to as a shallow trench isolation (STI) etch. Figure 5B illustrates the stacked gate region at this stage of the method.

The photo resist 505 is removed, field oxide 507 is deposited into the trenches and mechanical planarization is

performed at block 407. For example, chemical mechanical planarization (CMP) could be used as one type of mechanical planarization. Figure 5C illustrates the stacked gate region at this stage of the method.

5           An oxide etch back is performed at block 408 to remove a determined amount of the field oxide 507 so that the field oxide 507 is below an upper surface of the FG poly layer 503 and above the upper surface of the tunnel oxide layer 503. Figure 5D illustrates the stacked gate region after the oxide etch back has been performed. The nitride layer 504 is removed at block 409. The nitride layer 504 can be removed by a process such as etching. Figure 5E illustrates the stacked gate region after the nitride layer 504 has been removed.

          After the nitride layer 504 has been removed, a second polysilicon layer 508 is deposited over the stacked gate region at block 410. The second polysilicon layer 508 may also be referred to as FG poly 2. Figure 5F illustrates the stacked gate region at this stage of the method.

20           A spacer etch is performed to remove portions of the second poly layer 508 at block 411 leaving the floating gate poly wings 509 of figure 5G. A spacer etch is a method of selectively etching.



Other conventional steps of processing may be performed on the stacked gate region such as, oxide nitride oxide (ONO) formation, control gate (CG) poly deposition, CG poly photolithography and etch, and the like.

5           Figure 6 illustrates a method of fabricating the stacked gate region illustrated in figure 2. Figures 7A, 7B, 7C, 7D, 7E and 7F illustrate stages of the method of figure 6.

10           A substrate 701 is provided at 601. The substrate 701 is, generally, a silicon substrate. A tunnel oxide layer 702 is formed over the substrate 701 at 602. A self aligned floating gate (SA-FG) poly layer 703 is formed over the tunnel oxide layer 702 at 603. A nitride layer 704 is formed over the SA-FG poly layer 703 at block 604. Figure 7A illustrates the stacked gate region at this stage of the method.

15           A layer of photo resist 705 is deposited over the nitride layer 704 in selected areas by utilizing a mask at block 605. The areas covered by the photo resist indicate areas not to be etched and permit forming gates of the stacked gate region. The stacked gate region is etched at block 606. Layers and substrate  
20           are removed by the etch to form a shallow trench as shown by 706 in figure 7B. The etch performed at block 606, is also referred to as a shallow trench isolation (STI) etch. Figure 7B illustrates the stacked gate region at this stage of the method.

The photo resist 705 is removed, field oxide 707 is deposited into the trenches and a mechanical planarization is performed at block 607. An example of mechanical planarization which may be used is CMP. Figure 7C illustrates the stacked gate region at this stage of the method. An oxide etch back is not performed.

The nitride layer 704 is removed at block 608. The nitride layer 704 can be removed by a process such as etching. Figure 7D illustrates the stacked gate region after the nitride layer 704 has been removed.

After the nitride layer 704 has been removed, a second polysilicon layer 708 is deposited over the stacked gate region at block 609. The second polysilicon layer 708 may also be referred to as FG poly 2. Figure 7E illustrates the stacked gate region at this stage of the method.

A spacer etch is performed to remove portions of the second poly layer 708 at block 611 leaving FG poly single sided ears 709 of figure 7F to increase capacitive coupling of memory cells of the stacked gate region. Figure 7F illustrates a stacked gate region after the method has been performed.

Other standard steps of processing may be performed on the stacked gate region such as, oxide nitride oxide (ONO) formation,

CG Poly deposition, CG poly photolithography and etch, and the like.

Figure 8 illustrates a method of fabricating the stacked gate region illustrated in figure 3. Figures 9A, 9B, 9C, 9D, 9E, 9F and 9G illustrate stages of the method of figure 8.

A substrate 901 is provided at 801. The substrate 901 is, generally, a silicon substrate. A tunnel oxide layer 902 is formed over the substrate 901 at 802. A self aligned floating gate (SA-FG) poly layer 903 is formed over the tunnel oxide layer 902 at 803. A nitride layer 904 is formed over the SA-FG poly layer 903 at block 804. Figure 9A illustrates the stacked gate region at this stage of the method.

A layer of photo resist 905 is deposited over the nitride layer 904 in selected areas by utilizing a mask at block 805. The areas covered by the photo resist indicate areas not to be etched and form gates of the stacked gate region. The stacked gate region is etched at block 806. Layers and substrate are removed by the etch to form a shallow trench as shown by 906 in figure 9B. The etch performed at block 806, is also referred to as a shallow trench isolation (STI) etch. Figure 9B illustrates the stacked gate region at this stage of the method.

The photo resist 905 is removed, field oxide 907 is deposited into the trenches and mechanical planarization is

performed at block 807. CMP is an example of a type of mechanical planarization that may be used. Figure 9C illustrates the stacked gate region at this stage of the method.

The nitride layer 904 is removed at block 808. The nitride layer 904 can be removed by a process such as etching. Figure 9D illustrates the stacked gate region after the nitride layer 904 has been removed.

After the nitride layer 904 has been removed, a second polysilicon layer 908 is deposited over the stacked gate region at block 809. The second polysilicon layer 908 may also be referred to as FG poly 2. The second polysilicon layer 908 is deposited to a selected thickness or height which corresponds to a desired capacitive coupling. Figure 9E illustrates the stacked gate region at this stage of the method.

A spacer etch is performed to remove portions of the second poly layer 908 at block 810 leaving FG poly single sided ears 909 in figure 9F.

A field oxide etch back is performed at block 811 to remove a selected amount of field oxide such that the field oxide is below the SA-FG poly 903 but above the tunnel oxide 902. The selected amount of field oxide is removed to create FG poly double sided ears 910 as shown in figure 9G by removing the field oxide 707.

Other standard steps of processing may be performed on the stacked gate region such as, oxide nitride oxide (ONO) formation, CG Poly deposition, CG poly photolithography and etch, and the like.

5           Figure 10 is an illustration of a computer system 1012 that can use and be used with embodiments of the present invention. As will be appreciated by those skilled in the art, the computer system 1012 would include ROM 1014, mass memory 1016, peripheral devices 1018, and I/O devices 1020 in communication with a  
10           microprocessor 1022 via a data bus 1024 or another suitable data communication path. The memory devices 1014 and 1016 can include stacked gate regions fabricated according to the various  
15           embodiments of the present invention. ROM 1014 can include EPROM or EEPROM or flash memory. Mass memory 1016 can include DRAM, synchronous RAM or flash memory.

For the purposes of describing and defining the present invention, formation of a material "on" a substrate or layer refers to formation in contact with a surface of the substrate or layer. Formation "over" a substrate or layer refers to formation  
20           above or in contact with a surface of the substrate. A "flash memory device" includes a plurality of memory cells. Each "memory cell" of a flash memory device can comprise components such as a gate, floating gate, control gate, wordline, channel

region, a source, self aligned source and a drain. The term "patterning" refers to one or more steps that result in the removal of selected portions of layers. The patterning process is also known by the names photomasking, masking, photolithography and microlithography. The term "self-aligned gate" refers to a memory device where the gate electrodes are formed before the source/drain diffusions are made.

Many other electronic devices can be fabricated utilizing various embodiments of the present invention. For example, memory devices according to embodiments of the invention can be used in electronic devices such as cell phones, digital cameras, digital video cameras, digital audio players, cable television set top boxes, digital satellite receivers, personal digital assistants and the like.

Having described the invention in detail and by reference to preferred embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims. Other suitable materials may be substituted for those specifically recited herein. For example, the substrate may be composed of semiconductors such as gallium arsenide or germanium. Additionally, other dopants may be utilized besides those specifically stated. Generally, dopants are found in groups III

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and V of the periodic table. Other placements of the polysilicon wings or ears with respect to a floating gate may be used and still be encompassed by the present invention.

What is claimed is:

1. A semiconductor device comprising a substrate, a floating gate, a polysilicon wing, and a polysilicon ear, the polysilicon wing and the polysilicon ear being disposed on opposite sides of the floating gate, the polysilicon wing and the polysilicon ear being disposed on opposite sides of the floating gate, the polysilicon wing and the polysilicon ear being disposed on opposite sides of the floating gate.